rib or interspace of a given size will drain more perfectly than one at the usual level, and will better prevent the entrance of air, since the pus will be constantly escaping and tending to fill the space in and around the tube. There will be little or no danger of the drainage-tube falling into the empyemic cavity, since it must travel against gravity to do so, and if this accident happened the tube probably could easily be reached and removed with a forceps, because gravity would prevent it from moving away from the opening. In some cases the much-thickened pleura is the result probably of the organization of layers of fibrin deposited in the acute stage.

Of the five massive empyemas treated with dependent drainage it may be said that the time necessary for a cure was less in all than the average determined by Schädler, fourteen and one-half weeks, or the average in Fraley's cases, ninety days, and therefore there were no persistent sinuses. In the 9 cases there were no deaths. The method deserves further trial and study.

THE EFFECTS OF EXPOSURE TO INTENSE HEAT ON THE WORKING ORGANISM.[1]

By Charles N. Fiske, M.D.,
SURGEON, UNITED STATES NAVY.

The navy has been consulted in the matter of affections caused by heat and other attending conditions of the atmosphere in which its men work, because this class of disability has attracted attention in the public press and occasional medical reports, either in time of war or in the course of cruises in which the reading public is more or less interested, by reason of prostrations and deaths being noted in published dispatches.

The accompanying statistical table, which records but twenty deaths and thirty-three invalidings from the service on account of heat-stroke during the last thrty-five years, and the damage curve would indicate that heat prostration has been of comparatively little importance to the service as a whole; however, from the excerpts from sanitary reports of naval medical officers to follow and the fact that considerable numbers of cases have on occasion jeopardized the strategic or diplomatic mission of a particular warship, the deep concern of the immediate hygienist will appear to be justified.

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[1] Read in Section IV, XVth International Congress on Hygiene and Demography, Washington, D. C., September 24, 1912.

Heat prostrations were coeval with the "new navy" of the last quarter century, which found its beginning in the famous "white squadron;" correspondingly as that early class of all steam-propelled cruisers and gunboats has been retired, and its lessons in sanitation, and notably in ventilation, have been used profitably in the design and equipment of all but the earliest class of battleships and armored cruisers, the factor of heat-stroke in the navy has assumed relatively a low value during the last few years.

Naval hygenists, who have agitated changes in construction, arrangement, and ventilation of ships will represent that the service has largely solved the problem, while other observers will, with perhaps equally good reason, maintain that the difficulty has solved itself on account of smaller boilers and more economical leads of steam pipes and arrangements of pumps, etc., in the engine rooms of large ships. The latter view, however, is refuted by the still lower location of dynamo and steering engine compartments, and in the main it will be evident that improved facilities for ventilation, whether natural or artificial, have achieved the subsidence of heat prostration. It is only when a radically new type of ship is placed in service that faulty and inadequate ventilation any longer occasions suffering and disability from undue atmospheric heat and humidity, as has been recently shown to occur on the first ships of the *Dreadnaught* type.

At their worst, heat affections have developed only on isolated occasions, and then only on comparatively few ships, and doubtless many cases have been so trivial that they have hardly been recognized as of such a nature in the absence of severe cases.

This statement will prepare the physiologists and pathologists who look for some apology or explanation for the naval surgeons not making more definite contributions and exact observations relating to the fairly typical cases of heat exhaustion that occur in the service. It is perhaps thought that with his training, time, equipment, and opportunity to study the condition at its inception, something more than a mere compilation of general data should be available from the reports of naval surgeons for this paper. Such versatility, however, as the wide range of duties demands of naval medical officers, together with the lack of experience and apparatus to make the precise observations which would enable physiologic study to withstand criticism, and the uncertainty of having the cases, which nearly always occur under the unusual and unanticipated conditions on a ship in the tropics, remote from laboratories, as well as the fact that these occasions are likely to find the doctor most busy, preclude the contributions for which we all seek, and which should be more practicable near steel mills, for instance, where cases frequently may be expected and where provision can be made for such study.

The perusal of the literature of disorders attributed to heat tends to confuse the student first as to nomenclature and terminology and almost hopelessly as to etiology. Within the naval reports comparatively few titles have been used, probably fewer than if more had been available on the printed classification, and save for the quotations from the text of the reports themselves, little dependence can be had upon just what train of symptoms a title was used to cover some fifteen years ago when heat affections were most prevalent in the navy. For these reasons I have combined in the table all heat cases without regard to prevailing nosology.

One of the earliest references to heat prostration in the fire rooms of ships published by an American naval surgeon is the following by Medical Inspector A. L. Gihon, in his *Naval Hygiene*, of 1872:

"The symptoms of insolation often occur among men not exposed to the direct rays of the sun—in the fire room of steamers, on board the monitor class of armored vessels, in small, ill-ventilated cells. Dr. Kitchen informed me that while surgeon of the monitor *Dictator* it was common for men to be brought to him for treatment with coma, stertorous breathing, great heat of skin, full, quick pulse, and often convulsions. The cause was manifestly enough the exhausting labors of a watch in the fire room, where the temperature averaged 145°, and where the ventilation was exceedingly defective, air that had been already respired being repeatedly returned. Maclean states that 'insolation has frequently been observed on board ship, but almost always under conditions similar to those in barracks—that is, where overcrowding and impure air are added to the influence of excessive heat. Insolation is not uncommon on board the mail steamers in the Red Sea in the months of August and September; it has been observed that most of the cases occurred while the sufferers were in the horizontal position in their ill-ventilated cabins,' and he quotes the following: 'Assuredly,' says Dr. Butler, surgeon of the third cavalry, 'those barracks most crowded, least ventilated, and worst provided with punkahs and other appliances to moderate excessive heat, furnished the greatest number of fatal cases.' Surgeon Longmore, of the nineteenth regiment, notes that one-third of his cases and nearly half the deaths occurred in one company of the regiment quartered in the barrack, which was manifestly the worst conditioned as to ventilation, and, indeed, in every sanitary requirement. M. Bassier, a surgeon in the French navy, reports that the man-of-war brig *Le Lynx*, cruising off Cadiz, in the month of August, had eighteen cases of insolation out of a crew of seventy-eight men. The heat was excessive (91° to 95°), and much aggravated by calms. The ship was overcrowded, offering little space for the berthing of the crew. M. Boudin quotes the case of the French man-of-war *Duquesne*, which, while at Rio de Janeiro, had a hundred cases of insolation, out of a crew of six hundred men.

Most of the men were attacked not when exposed to the direct heat of the sun, but at night when in the recumbent position—that is, when breathing not only a hot and suffocating, but also an impure air."

The works of Surgeon Joseph Wilson, U. S. N., 1870; Medical Directors T. J. Turner, 1879, and A. Gorgas, 1897, and Medical Inspector H. G. Beyer, 1908, include but passing references to heat affections.

Medical Inspector J. D. Gatewood, in his *Naval Hygiene*, 1909, writes:

"About 90 per cent. of all troubles ascribed to heat come from a part of the service—the engineer force in cruising ships serving under conditions that put a large load on the kidneys while depriving them of the fluid necessary to flush themselves properly. The result is a great concentration of irritating urine, and perhaps even anuria if, while the body is bathed in warm sweat, there is a sudden checking of perspiration and rapid chilling of bodies under ventilators or fans. . . . If during the year 1905 all the firemen and coal-passers had been at sea the entire time, there would have been about 200 admissions for heat troubles from each 1000 firemen and coal-passers so employed, and in the year 1899, about 400, *other conditions remaining the same.*

"The intensity has relation, however, to atmospheric conditions while underway and to the course of the ship in relation to wind, high outside temperature, with high relative humidity, and relative state of calm producing the maximum result. The hearts and kidneys and stamina of men, if much speed is maintained, are then greatly tried, especially if new men, some perhaps not well selected, are working as coal-passers. It would therefore seem that, in a general way, tropical cruising, especially in our summer months, and an increasing percentage of recruits in the engineer force tend to that condition in the service known as heat prostration. For instance, the records show that in 1898, when owing to the Spanish-American War there were relatively large number of recruits and several summer months of general tropical cruising, though chiefly at reduced speed, the admission ratio for cruising ships was 29.4. . . . At present the nature of the so-called heat prostrations in fire rooms is not well understood. It appears that when men are working in hot air they are able to perform their duties without much distress, when the standing of the wet bulb thermometer is not much above 81°, but when that bulb approaches 86° to 88° the disinclination to work becomes very marked. However, the form of heat prostration may not be due to the direct condition of contained air as shown by thermometer readings, but may be precipitated by rapid variations of skin temperature incident to exposure to drafts under ventilators in natural ventilation or to currents incident to assisted or forced drafts when applied to a fire room already containing men who have been subjected to very high temperature.

"At any rate, it has seemed that the tendency to heat prostration has become quite marked at times just after assisted draft has been started. It may be considered that if fire rooms were kept under assisted draft the cases of heat cramps would be greatly diminished, but that the use of assisted draft only occasionally to meet special conditions may be responsible for a number of such cases at some particular time."

The air of fire rooms has probably always been of sufficient chemical purity so far as adequate oxygen and minimal carbon dioxide are concerned, and there is no evidence that carbon monoxide from the furnaces or coal oxidation on the floors has accumulated to produce any such toxic symptoms as are commonly attributed to heat. That this distress tending to heat prostration is a matter of heat and humidity preventing automatic cooling of the body by evaporation of sweat and by convection to circulating air, as shown last year by Mr. Leonard Hill, of London, was surmised years ago is indicated by the following extracts from sanitary reports:

Surgeon Geo. H. Cooke, reporting on the U. S. S. *Mohican,* in 1885, said:

"It was while cruising along the Mexican coast during the rainy season [July and August] and in the warm water and hot murky weather of that region that numerous cases of prostration from heat occurred, as well among the men on deck as with those in the fire room."

Surgeon John C. Wise, on the U. S. S. *Jamestown,* in 1886, said:

"Two deaths occurred during the year: one, a case of insolation happened when the thermometer stood at 85°, showing the importance of care in this respect, especially when there is great atmospheric humidity, which so often prevails in the West Indies."

There are probably few medical officers who would now fail to to affirm the belief of Chevers, Manson, Castellani, and other eminent authorities that of the predisposing causes of heat-stroke, alcohol habituation, or even occasional alcoholism, is one of the greatest factors. While I personally believe the navy would be almost infinitely better off if total abstinence could be enforced, and the medical department and messes of ships quite as well administered, if no spiritous, vinous, or malt liquors were permitted on board ship, still, given men who frequently indulge, that there is another side to the practical question is evidenced by the following opinions and practices of former naval surgeons:

P. A. Surgeon G. P. Lumsden, reporting on the U. S. S. *Boston* en route from New York to Jamaica and Central America, October, 1888, says:

"The firemen complained of the heat of the fire room, which had a temperature of 140°, and several cases of heat exhaustion occurred; the first on October 6th, the second day out from Sandy Hook. After this one ounce of whisky was given each fireman, who brought a card from the engineer at the end of his watch. This seemed to have a beneficial effect, as there were fewer complaints after this, and they appeared to work more cheerfully. At Port Royal fifteen gallons of Jamaica rum were purchased by order of the captain, upon the recommendation of the surgeon, which was served out in one-ounce doses as stated above, and it lasted until within a few days of New York."

Surgeon E. H. Green, on the U. S. S. *Marblehead*, reported in 1894:

"The temperature of this [berth] deck with the dynamo running was from 90° to 92°, rendering it almost impossible to obtain refreshing rest. The fire room has had a temperature as high as 140° [the author observed it 186°, July 13, 1906]. Usually it is 120°, the engine room being from 105° to 110°. There were several cases of heat exhaustion, though none of them of a serious nature. While cruising in the tropics it was found necessary to give stimulants at the end of each watch: one and one-half ounces of rum were given, and it had good effect, as it kept the men up to their work, looking forward to the dram at the end of the watch, and it restored the exhausted system materially."

Surgeon Howard E. Ames' report on the U. S. S. *Detroit*, for 1895, says:

"It is here I will make a few remarks upon the engineer's force, based upon observations made upon this vessel, and which, I think, apply to the whole service. The modern warship is a series of small compartments, demanded for strength and security. This compartment system is followed in the coal bunkers. When under steam in hot weather, these bunkers are not properly ventilated, and in addition to this the heat is too great. The deficiency of fresh air is not so serious a defect as the high temperature which surrounds the men while working. During the summer we were up the Yang-tse River, and during that trip the temperature of the coal bunkers ranged from 115° to 127°, while the outside temperature on deck was from 95° to 100°. If the engineer's force is expected to maintain its efficiency it is important that some scheme be devised to overcome this excessive temperature. It is absurd to expect nature to overcome a temperature of 28° under such conditions, and no human being can work efficiently in such a temperature without permanent injury to his physical and vital constitution. Take in addition to the heat, the *motionless*, impure air of the bunkers, filled with coal dust, constantly clogging the sweat glands of the men, and a moment's thought will picture their deplorable condition. During the trip it was only by giving each fireman and coal-passer two ounces of whisky at the end of his four-hour watch that we were able to keep them at work and accomplish the trip. We had several cases of heat prostration, none of which was fatal. The men at the end of the watch were almost collapsed, *streaming with perspiration*, accompanied by *stertorous breathing, rapid pulse*, and trembling limbs. The eight hours' rest was not sufficient to restore them sufficiently to consider them efficient men.

"This exhaustion was not due to the work, but to the abnormal conditions surrounding the workers. This is shown by the weight of the coal handled on this trying trip. The general consumption during one day was 26 tons, the daily average for the trip being 18 tons. If we admit that this average was handled twice, it would give us but 36 tons handled in twenty-four hours by 30 coal-passers, or 1.2 tons per day per man, and this work was not continued beyond four hours. Such light physical exertion under normal conditions would scarcely be appreciated in its effect on the physical organization of a healthy laboring man. In this case we are forced to consider the degraded air and the heat as the cause. We can practically eliminate the degraded air of the bunkers by considering the amount of work done under similar conditions, but in a temperature below that of the body. We are forced to admit that it is principally due to excessive heat."

Extract from report on the U. S. S. *Bennington*, 1898, by P. A. Surgeon E. P. Stone:

"The men of of the engineer's force, all of whom swing in the wing passages and after berth deck, after four hours of severe and arduous toil in the frightful temperature of from 140° to 150°, would come off watch and endeavor unsuccessfully to get rest and sleep in the only comparatively less trying temperature of from 90° to 100°. Unable to sleep, worn out with fatigue, and annoyed by prickly heat, it would be jaded and discouraged men who would respond to the next call to go below on watch. Is it to be wondered at that the medical officer is called upon to furnish stimulants to keep these men up to their duty? Is it to be expected that men in such a condition can do efficient work? And may not a fire-room force in such a plight seriously cripple the fighting efficiency of a ship, as my predecessor has pointed out in his report? . . . It has been the custom on this ship to give, when under way, each watch in the fire and engine rooms some liquor, either during or at the end of the watch. On our way here from San Diego I conformed to the custom after the first few days, principally for its mental effect on the men, as they expected it, and furnishing the liquor served to keep them contented. I have not had enough practical experience yet to feel like making a positive statement, but so far as my experience goes it has inclined me to be opposed to the issue of spirits to men subjected to high temperatures. It produces a temporary stimulation, but leaves the men ultimately in a state of lessened resistance. I believe a better stimulant, and a useful prophylactic, is the administration of strynchine. In those cases of heat prostration that give rise to muscular cramps, I believe, theoretically, that subcutaneous injections of normal salt solution ought to give relief."

Extract from report on the U. S. S. *Massachusetts*, 1899, by Surgeon S. H. Dickson:

"I had been led to expect, under the circumstances of war and during a close blockade and operations in the tropics of such duration in the summer months, that many cases of heat prostration among the 100 men of the engineer force would be encountered. With fires lit all the time, and steam all over the ship; bottled up, so to speak, every night, with temperatures in the fire rooms frequently and for hours at a time from 144° to 150°, in the engine room rarely below 120°, conditions were constantly favorable for their development; and yet but fourteen cases in all were admitted to the sick list, and these occurred after the removal of the strain and excitement of actual hostilities, and none of them of a serious character. Careful hygienic measures, such as frequent opportunities for bathing and washing, and the intelligent and constant use of the ventilating blowers, supplying an abundance of fresh air, undoubtedly led to this result. On only one occasion, and for a brief period during the voyage from Porto Rico to Cuba, was it considered necessary to issue a small spirit ration to the engineer division. It put heart into the men and was productive of nothing but good. It was given to each watch on coming off duty and after they had washed and cooled off."

Extract from report on the U. S. S. *Columbia*, 1899, by Surgeon C. G. Herndon:

"A number of men at various times were more or less overcome by heat in the dynamo, engine, and fire rooms, and were promptly brought to the sick quarters. The heart and not the brain was the organ which had given out among these men. The routine practice was to stretch the man out on the cofferdam, with the head low, loosen all tight clothing, and give him a liberal dose of whisky or brandy, with digitalis. Usually in a short time he would go off into a quiet sleep, and wake up ready for work.

"I am opposed to the routine issue of alcohol to the men below while on watch; but from my experience, and more particularily on this ship, I believe it would be well, if the Bureau sees fit to do so, to increase the amount of whisky in the medical supplies and allow the medical officers to give it to deserving men coming off watch when they show markedly the effects of the long exposure to the high temperature in which they work.

"I have seen various stimulants used, but nothing, in my experience and belief, does these men as much good when coming off watch as a ration of whisky diluted with water, and, if necessary, with some digitalis added."

Surgeon M. H. Simons, on the U. S. S. *Iowa*, 1899, reported: "During the trip to San Juan, and on one or two other occasions when the heat was great, the men in the engine and fire rooms drank so much warm water that nausea and vomiting often occurred, and nothing would be retained. We found that under these circumstances the trouble could be checked and even avoided by a moderate dose of alcoholic stimulant (part of the time we used alcohol itself), with capsicum, gentian, or hydrastis. This dose seemed to put the stomach in proper tone for the digestion of food, and to lessen the thirst. As a preventive it was given when the men came off watch. Heat prostration was treated by putting the man in a bunk with a wet towel over his face and head and giving 0.6 gram of acetanilid; in one hour, if the temperature still stood above 100°, 0.3 gram was given until the temperature stood below 100°, and then a bath was given, in which the patient lay for fifteen minutes; the water was at first warm and then gradually cooled to the temperature of the sea water in the pipes, probably about 76°. The acetanilid equalized the circulation and subdued the nervous symptoms; the lukewarm bath seemed to aid this and to exert a specially and noticeably good effect on the digestive tract."

In discussing "The Alcohol Question in the Navy," Medical Director P. A. Lovering, who was surgeon of the U. S. S. *Oregon* during the Spanish-American War, stated:

"I remember that on the cruise of the Oregon around from San Francisco, Captain Clark every day at his own expense furnished the firemen coming off the afternoon watch with a drink of spirits. It encouraged the men, did good, and I was glad that I could recommend it as a beneficial measure."

From our more recent knowledge of the precise nature of the action of alcohol in small doses it seems evident that the benefits noted in the foregoing reports were psychical and doubtless attributable to the narcotic effect; alcohol in these cases probably induced a more comfortable frame of mind, indicating consideration upon the part of officers in authority, and withal favored relaxation akin to that sometimes given after disease or injury to relieve undue apprehension. It is significant that no naval reports of the last decade refer to the use of alcohol either in prophylaxis or treatment.

With reference to the well-known advantage of having ships painted with light reflecting surface, Medical Inspector T. C. Walton, reporting on the U. S. S. *Chicago*, in 1899, says:

"Changing the color of the outside of the ship from black to white is believed to have lowered the temperature on this [gun] deck, during the summer days when the sun shone on the ship's sides, from 4° to 6°. . . . During the speed trials of this ship at Newport in September last the temperature in those parts of the engine rooms was recorded as high as 129°. The air at the time was laden with moisture from escaping steam. A prolonged stay there was described as being unbearable. The engineers on duty were quickly prostrated. Efficient ventilation was urged."

Inadequate ventilation and removal of heated air on the earlier all-steam propelled ships is attested by the following quotations:

Medical Inspector G. W. Woods reported on the U. S. S. *Charleston* in 1890:

"The heat of the dynamo room is often so great that the thermometers, indexed for 140°, cannot register the temperature, and the men perform their work entirely naked, complaining of nausea and vertigo whenever the revolutions of the little electric blower are even for a brief period suspended."

Surgeon T. H. Streets reported on the U. S. S. *Bennington* in 1893:

"The temperature of the fire room previous to these changes [new hatch opened and new ventilators] was frequently as high as from 140° to 150°. The temperature has been materially reduced. The highest it has reached since the opening of the hatch is 112°."

On the U. S. S. *New York* January 11, 1894, Medical Inspector Edward Kershner found the temperature of living and working spaces to range from 88° to 108° throughout the ship when the outside air registered 82°, although the trade winds blew at the rate of 6 knots on the port bow, the ship making 13 knots under but four boilers, and burning but eighty-five tons of coal per day.

Likewise in 1894 Surgeon W. G. Farwell reported on the U. S. S. *Columbia:*

"The temperature of the engine and fire rooms is excessive when firing hard; the temperature of the fire room ranges from 140° to 150°, and that of the engine room from 105° to 110°; when firing immediately the temperature is respectively from 120° to 125° and from 98° to 100°. . . . the temperature of the cabins opposite (the engine room hatches) was 90°, an almost unbearable degree of heat for a sleeping room."

The recording of excessively high temperatures was the rule rather than the exception for a few years prior to and immediately following the Spanish-American War of 1898.

Surgeon C. A. Siegfried reported on the U. S. S. *Cincinnati* in 1894:

"In the dynamo rooms by means of electric (additional) blowers the temperatures have been reduced 20°, and they now rarely rise above 110°. . . . The ventilation of the engine room is very unsatisfactory, and temperatures are recorded from 90° to 170°. . . . I have myself recorded fire-room temperatures as high as 168°. In the engine room, lower platform, the average is about 102°, on the upper platform it frequently reaches 135°."

Surgeon E. Z. Derr, on the U. S. S. *Raleigh* in 1894 and 1895, reported:

"The inadequacy of fire-room ventilation made itself manifest on the first trial trip to Hampton Roads. Steaming half power the temperature of the starboard forward fire room in the boiler interspace, five feet above the floor, reached 180°. Three men were exhausted by the heat. On September 10, steaming under the same easy conditions, it reached the same, and two men were exhausted. On September 11, 190° was recorded. On the fire-room galleries, where the blowers were located, the thermometer registered 205°, rendering it impossible for the men to superintend them, and accordingly they were not used. The fire rooms were therefore dependent upon natural ventilation alone, and that supplied by the ventilation was wholly inadequate to keep down the temperature."

Medical Inspector J. G. Ayres, on the U. S. S. *Olympia* in 1895, reported temperatures of 180° and above in two of the fire rooms which had no blowers.

Surgeon C. A. Siegfried, again in 1895, on the U. S. S. *Texas*, said:

"It is to me doubtful if any possible system of ventilation in some of these spaces would correct the high temperature ranging from 125° in dynamo rooms and redoubt to 170° in hydraulic pump rooms. When the ship is under way the heat becomes excessive and during the short periods of time when making steam trials last September the number of cases of heat exhaustion treated in one day, aggregated twelve. The hydraulic rooms furnished most victims, hence the more thorough covering of the hot metals, pipes, etc., with non-conducting materials becomes imperative."

The improvement made on the U. S. S. *Cincinnati* in 1895 is shown by the report of Surgeon L. B. Baldwin, in which he showed average temperatures of fire room No. 1 to be 143°, 188°, 187°, 184°, 189°, 191°, and 109°, with a maximum of 204° between June 30 and May 12. After some changes in the management of the blowers the average temperature was reduced to 126° and 139°, with a maximum of 170°. The average for the year in this fire room was 145.8°.

The Surgeon General's report of 1897, covering the year 1896, stated:

"Of the 59 cases of heat-stroke, 40 were caused by heat in fire and engine rooms, 7 of the latter being returned from the *Raleigh*, 5 from the *Indiana*, 4 each from the *Amphitrite* and *Massachusetts*, 3 from the *Maine*, *Newark*, and *San Francisco*, and 2 each from the *Cincinnati*, *Alert*, and *Marion*, the remainder (5) occurring scattered, 1 on each ship."

Surgeon Robert Whiting, on the U. S. S. *Monterey* in 1895, reported:

"The continued strain of resisting the high degree of heat early began to tell upon the men of the engineers' force. The closed fire room of the *Monterey* has no outlet overhead, the doors opening on one side into the overheated engine room and on the other into the berth deck. The forced draft ventilation not being in use, it was discovered that the fire room was fed by hot air from the engines on one side and on the other by air that had been devitalized by use on the berth deck. The medical officer upon one of his inspections found the temperature as high as 147°. There were a number of cases of exhaustion and vomiting, most of which were treated without entry upon the sick list.

"The drills at general quarters, which were more frequently performed than any others, required the use of steam in the pump rooms underneath the ward-room officers' quarters and under the berth deck. It will be observed by reference to the temperature charts that these pump rooms registered the highest degree of heat, 180°. It required hours to bring the atmosphere in the ward-room down to 90° after these drills were concluded. The dynamo room, contiguous to the forward turret and underneath which the forward pump room is located, the main compartment of the berth deck separated from it by a steel bulkhead, suffered in similar fashion."

Surgeon James E. Gardiner's report on the U. S. S. *Amphitrite* in 1896, stated:

"So far the most serious trouble developed has been the one of the high temperature generated on the modern iron and steel ship filled with engines and imperfect means of ventilation so far devised to relieve the evil. From the records of the medical journal the suffering from this cause while the ship was cruising during the months of July and August was great. Temperatures as high as 183°, in the fire room are recorded, with 167°, given as the minimum during the twenty-four hours of that day. In the engine room for the same day are recorded 155° as maximum and 148° as minimum; the berth deck, 102° maximum; a state room in ward room, 98°. There were numerous cases of heat prostration, cases of myalgia, cramps, and sudden diarrheas. A board appointed by the commanding officer, after carefully collecting the data, made its report, and the ship was ordered to the navy yard at Norfolk, where the changes were made. Since then the conditions have greatly improved. No test as severe though as that of last summer's cruising has been made since the change, but it is believed that no such temperatures will again be reached."

Extensive temperature observations made by Medical Inspector

J. G. Ayres in the dynamo room of the U. S. S. *Olympia* in 1896 gave the maximum as 121° and mean as 113° for August and 113° and 105° for October. In the same year the dynamo room of the U. S. S. *Columbia* was found to have a temperature range from 110° to 125°, and the steam-steering room exceeded 120°, with defective ventilation.

The means for adequately heating certain living spaces in ships often proved intolerable to other compartments as is shown by Surgeon W. S. Dixon's comment on his own state room on the U. S. S. *Brooklyn* in 1897:

"No less than seventy-five feet of steam pipe (heating) are very close to the berth—some of it within two inches and none of it more distant than forty inches. Five pipes pass through the room, and four are separated from it only by a thin metal bulkhead. Until the five pipes (forty-five feet) had been additionally covered with felt, one could not sleep in the bunk. With an outside temperature of 19°, that of this room was 90°, as determined by reliable thermometers, and the air duct was delivering cold air in the room at the time. In one of the double berth rooms of the junior officers two thinly covered steam pipes pass along the whole length of the upper berth, and in such close proximity that a man of ordinary proportions could scarcely crowd in between the mattress and pipes. It would be impossible for anyone to sleep there while steam was being used to heat the ship."

Surgeon W. R. Du Bose reported from the U. S. S. *Terror* in 1897:

"Practically the ship has done no cruising, and exactly what temperatures will be experienced remains to be seen. In the short trips made the engine-room temperature has been 118°, the fire room 116° to 142°, generally 122°; the forward turret machinery space, 124°. In the superstructure during a heated term in July and August a temperature of 110° was several times noted. No case of heat exhaustion has occurred."

Surgeon P. A. Lovering, on the U. S. S. *Oregon* in 1897, reported:

"The berth deck is also very warm, as it is over the main boilers, and in it is placed the auxillary fire room. When the vessel is underway the temperature often rises to 100° and even higher, and rarely falls below 85°. The forward compartment of the citadel is fairly lighted by twelve deck lights, but has no direct air supply. It is much cooler than the central compartments, as it is forward of the boilers.

"Each engine room has, besides the usual hatch, a blower for artificial ventilation. The temperature ranges between 90° and 100° when under way.

"Each of the eight fire rooms has a large ventilator, and also a blower for forced draft, which is used for ventilation. When under way the temperature has reached 135°, but is usually 5° to 10° lower. This temperature was in cool weather when the outside air was 60° or less, and it is probable that in warmer weather the fire rooms will be much hotter.

"There have been no cases of heat prostration."

The protests of some of our medical officers during this period were almost pathetic, as is seen in the following extract from the report on the U. S. S. *Bennington*, in 1898, by Surgeon John W. Baker:

"We should build our ventilators larger and higher and make them more numerous; provide our fire rooms, bunkers, and engine rooms with fans on a large scale, until we no longer are content that men should, in these days of modern science, toil and labor in a vitiated atmosphere at a temperature varying from 130° to 170°, until they are temporarily exhausted or permanently disabled, and that, too, long before the period assigned to men who live on deck in fresh air and wholesome sunshine, and who are never called upon to make the physical exertion, save in unusual emergencies, that these men must make every day, if we would maintain our speed at sea, speed and turning in evolutions—in fact, the efficiency that is not only desirable but absolutely essential for our success in warfare, and for which our ships are constructed."

Surgeon M. H. Simons, reporting on the U. S. S. *Iowa*, in 1899, stated:

"The ventilation of the distiller room is entirely inadequate, and the temperature is so high (145°) frequently that the man neglects his watch on the gauge to stand under the small cool-air inlet. The exit shafts for hot air in the dynamo room are so small that half the hot air collects in one or the other ammunition passage, increasing greatly the discomforts of those who must work there, especially in battle. The temperature of the dynamo room varies from 107° to 125°. . . .

"The state rooms for the officers in the citadel, at sea, in warm weather, have a temperature range of from 93° to 100°, artificial light has to be used all the time."

Surgeon John M. Steele, on the U. S. S. *Monadnock*, in 1899, reported:

"On entering the tropical zone, where the temperature of the air and water are nearly the same, and high, about 84°, the vessel heated up rapidly and remained so.

"The hottest part of the vessel in which men live is the superstructure and warrant officers' quarters. The warrant officers' quarters are next to the dynamo room, and separated by an iron bulkhead, and in the forward room the temperature averages about 95°. In the superstructure is situated the cabin and ward room, officers' quarters, also the galley, the officers' water closets, and the mens' head. These apartments are directly over the fire and engine rooms, and the heat here is high and continuous night and day, with an average of about 94°. There is a slight remission in the early morning hours. In addition to hatches, deck lights, and air ports the present means of ventilation should apply to the superstructure, and an active method of introducing fresh air, which could be accomplished by two additional blowers, to force air into the entire vessel. This addition would combine the plenum and exhaust, which I believe is necessary for the best effect for the health of the crew."

From a better ventilated gunboat, the *Annapolis*, in 1898, Assistant Surgeon S. B. Palmer reported:

"No excessively high temperatures have been noted in the engine and fire rooms, the two cases of heat exhaustion of mild grade which were treated were men unaccustomed to this work."

Asbestos sheathing helped to alleviate suffering in the living quarters abaft the engine room trunk of the U. S. S. *New York*, in October, 1899, where the temperature had formerly ranged from 98° to 110°. Medical Inspector C. U. Gravatt urgently advocated similar insulation in the dynamo room and evaporating room.

All evaporators are nowadays well covered with asbestos, conserving heat for their more economical operation and promoting comfort for their tending.

The surgeon of the "Flying Squadron," Medical Inspector Paul Fitzsimons, for 1898, stated:

"The fleet blockaded Santiago for five weeks, lying off the entrance about two miles in the open sea. Fortunately the trade winds were usually fresh, and no one suffered from the heat on the main and gun decks. The berth deck was like an oven. It was heated on the outside by the sun and inside by three smokestacks, the battle ports were closed and a moderate amount of air was driven by the blowers. The warrant officers' rooms were uninhabitable. The awnings could not be spread, and after a time the men were permitted to sleep in the open instead of sweltering below. They would lie on the forecastle wrapped in blankets, and no case of sickness was caused by it. The crew also worked in the sun coaling ship frequently without injury."

Since the Spanish-American War conditions have steadily improved and the unfavorable reports have come chiefly from the older armored ships, notably the *Monadnock*, *Massachusetts* (in the fire rooms of which Surgeon J. C. Byrnes reported in 1900 an occasional temperature of 210°, reduced 30° by changing location of blowers), *Monterey*, *Chicago*, *Iowa*, *Brooklyn*, *Illinois*, *Wisconsin*, *Albany*, *Oregon*, *Alabama*, *Newark*, *Kentucky*, *Colorado*, *Ohio*, and *West Virginia*. Many reports at hand from these sixteen vessels, while interesting, merely reiterate the high temperatures of the living and working quarters.

On the U. S. S. *Texas*, Surgeon H. E. Ames reported steering engine room temperatures of 110° to 115° and humidity "so great that there is no evaporation from the body . . . those of the crew who are stationed there at sea are exhausted at the end of two hours. "The firemens' wash rooms were "from 130° to 145°," and of course the air was saturated with moisture. Fire-room temperature under natural draft was 150°.

From the U. S. S. *Wisconsin*, in 1906, Medical Inspector H. G. Beyer reported as follows:

"Battleships and monitors will always be the most uncomfortable ships in a climate such as this (Cavite). With perfect sanitary conditions the constant high temperature and humidity from within and without are bound to cause a steady lowering of the average physical and mental strength and endurance of every human being on board. This generally acknowledged fact makes frequent change of station, especially for battleships, not only desirable but imperative.

"During the passage of this vessel from Hongkong to Cavite, between December 28 and 30, 1905, a series of heat prostrations occurred. Of the 14 cases, 10 were firemen, 2 water-tenders, and 2 coal-passers. The symptoms varied but slightly in the different cases, and were chiefly those of collapse, with dizziness, headache, and severe cramps in the legs, thighs, arms, forearms, back, and abdomen. In no case was there embarrassment of speech, although loss of voice was noted in one fireman, who stated that this was his second attack. Two of the cases did not show distinct symptoms of heat prostration until some little time after leaving the fire room, and one of the two was found unconscious.

"These patients were at first rubbed with towels soaked in hot water, with excellent results. Some in whom the cramps were painful and distressing were rubbed with chloroform liniment. Rest, of course, was enjoined upon them, and all were off the list and on duty two days after the arrival of the ship in port.

"The direct cause of the outbreak was the heat in the fire room, from what is known as assisted draft. In assisted draft the fire room is made as tight as possible, the air inlets and the furnace outlets being the only places in open communication with the fire room. But, unlike what happens during forced draft, when the blowers have their speed increased, and the incoming volume of air is very much greater than under ordinary draft, in assisted draft the incoming current remains the same, or may even be reduced.

"Several points in connection with the occurrence of this interesting series of heat prostrations seem to be unusual. The temperature in the fire room was not excessive, and alone could scarcely account for so widespread an effect; the relative humidity of the atmosphere was very high, and the temperature and moisture of the atmosphere suddenly increased the day the prostrations occurred. The afternoon we left Hongkong officers and men wore blue with comfort; the next morning white was ordered because of the sudden climatic change."

Of the smaller cruisers and gunboats complaints of high temperatures and humidity were made in reports from the *Petrel* (160°), *Isla de Luzon* (172°), *Albany* (136°), and *Princeton* (115°).

On the newly commissioned U. S. S. *Maine,* in 1903, Surgeon N. H. Drake recorded 45 cases of heat prostration:

"Fifteen admissions to the sick list for this condition and about thirty others were treated for vertigo and cramps in the muscles of abdomen and limbs. Only one of those admitted remained on the sick list more than two days, he being under treatment for five days. Many of those not admitted were excused for the whole or a portion of their watch below. This unusual number of cases was attributed to a combination of circumstances, viz., new men unfit for service in their ratings; varying temperatures caused by draughts and blowers; improper clothing of the men in the fire room; the use of too much cold water while on watch; drinking water unfit for use on account of chlorides, and extremely hard work in a climate to which many of them were unaccustomed."

Assistant Surgeon A. G. Grunwell, who later evolved the interesting theory that heat cramps might be occasioned by absorption of toxins of tetanus bacilli from intestinal contents, in 1900 treated heat stroke successfully by venesection in the walled city of Tientsin during the Boxer uprising.

The following extracts from the annual report of the Surgeon General of the Navy of 1909 show how recently heat affections seemed to deserve special attention.

"Heat exhaustion is less prevalent than it was two or three years ago for the reason that the small cruisers with poorly ventilated fire rooms have either been withdrawn from tropical service or placed out of commission. The opinion that heavy, muscular work has been a contributory essential, and that heat, humidity, and rapid cooling of the body are not the only causes, received some support from an observation of Passed Assistant Surgeon G. H. Hathaway, on the U. S. S. *Cheyenne,* which now burns oil fuel. This officer shows that 'during the standardization runs at maximum speed the termperature in the fire room rose to 140°, which is about 10° higher than under previous similar conditions when burning coal. Nevertheless, in this higher temperature no case of heat prostration occurred, nor during the cruise has any member of the engineer's force succumbed to the heat. It is thought that the slight amount of physical exertion required to regulate the burners, as compared to passing coal, enables the fire room watch to withstand a greater elevation of temperature. While cruising the number of men on duty in the fire room is reduced to about one-half those required for coal fuel, which is of some sanitary advantage.' . . . Just what factors enter into the causation of the condition known as 'heat prostration' observed in those exposed to excessive heat, either solar or artificial, particularly fire room, is not definitely known today. There have been a great many cases in the navy during past years, and though in 1908 a fewer number than usual were reported, and although effort has been made and is being made to improve the condition under which the engineer's force performs its duties, there seems no immediate prospect that the condition will cease to be an important type of disability."

Although not occurring on shipboard it would be amiss not to include in these extensive quotations the cases mentioned in an extract from the report of Surgeon G. A. Lung on duty with the First Regiment of Marines in the Pekin Relief Expedition of 1900:

"Two types of heat stroke were observed. The more common one was exhibited with extreme fatigue, mental depression, weak circulation, with perhaps partial loss of consciousness. The other appeared more suddenly, and was marked by hard, fast pulse, suffused face, bloodshot eyes, complete unconsciousness, and perhaps delirium, with muscular spasms of the entire body. These cases would appear while the column was moving or immediately on coming to a rest. If on the march they would stumble and fall in the roadway, or while sitting would suddenly topple over. The first intimation the medical officer would have would be the cry with stentorian insistence for the doctor, and on some days it came with startling frequency. They were carried to one side, an imperfect shelter from the sun for the head made by bending several standing cornstalks together and the best remedies at hand applied. If the patient appeared seriously ill a man was left with him, or several thus affected would be gathered together and one man look after all. In the meantime the column would move on, leaving them behind. The number who had convulsions was comparatively small. A large percentage became unconscious.

"August 10, was a peculiarly trying day, because of the heat. By noon fully seventy-five of the regiment had dropped out. It is true some of these were only badly wearied, and found an example in those who were more than wearied. There was, however, no shirking or malingering. Every man seemed to realize the character of the expedition and the purpose for which it was made. Indeed, it was sometimes touching to see a man with a determined expression trudging along, staggering from weakness and the weight of his accoutrements, and with a degree of illness that entitled him to a bed in a hospital. A few of the men, instead of dropping out at once, would gradually drop to the rear, where they would totter along, crying like a lost child, until relieved of their burden by a companion or forced to lie down and rest.

"A most remarkable feature of these cases of heat-stroke was the rapidity with which they recovered. Often without any treatment whatever, and by night, all by helping one another, or by getting a lift in a wagon or a ride on a horse, would overtake the column encamped for the night. The following day they would take their places in the ranks again. If the expedition happened to be near the river and junks were available the worst cases were sent on them for a day's rest.

"There were but two deaths from this cause, one occurring at the battle of Yangsung, and the other at Tungchow. Two were afflicted with mild melancholia, but after a short rest in the hospital they recovered."

Undoubtedly the most complete report on heat cramps by medical officers of the navy in recent years are those of Surgeon M. S. Elliott in the *Military Surgeon*, for March, 1908, and of Surgeon A. G. Grunwell in the *United States Naval Medical Bulletin*, for July, 1909; their clinical notes are too extensive to be quoted here and from the one autopsy by Elliott the only characteristic pathologic condition found was congestion of the kidneys.

Sun-stroke as typically occurring in the midsummer heat of our cities is now comparatively rare in the navy, the last published case being one observed by me off Acajutla, Salvador, in 1907, in the person of a boat-keeper of the U. S. S. *Marblehead*, who fell asleep and became unconscious in his boat, without awning cover, and experienced total amnesia for sixty-nine hours. Thermic fever does not appear to have been an important factor since the Spanish-American War, when 89 cases were recorded. During the twenty-five years from 1886 to 1910 inclusive there were returned 1507 heat cases, of which 64 per cent. were heat prostration (commonly of the exhaustion type), 32 per cent. were classified as thermic fever, and 4 per cent. as insolation. About one-third of the cases of thermic fever developed on shore, and doubtless the larger part of the few on board ship were ill-defined confusion cases.

So far as I can learn heat-stroke between decks among men not performing hard work is unknown in our navy; if it were now common for persons to be stricken in cabins or while asleep we should certainly look for the condition among our ten thousand man-o'-warsmen here about Key West and Cuba during the midsummer.

From the recorded and personally received opinions of naval medical officers I feel justified in affirming that the characteristic heat affection of the naval personnel has during the past quarter century been "prostratio thermica," heat exhaustion, largely confined to the fire room force; during 1909 and 1910 respectively, the admission rates per thousand for heat affection in the fire-room force were 8.45 and 7.91 respectively, while for the entire service they were 2.79 and 2.16 respectively, every other occupational group having ratios below the mean with the exception of the engineers' force, which were 3.26 and 2.78 for the respective years. This most common form, heat exhaustion, is believed to be a disease entity with either the systemic or muscular symptoms predominating, sometimes the one form almost to the exclusion of the other. The heat regulation centres do not appear to be so profoundly incapacitated as in sun-stroke, there being but slight fever or very commonly the subnormal temperature of shock; Marine Oberassistenzarzt Dr. Esch, however, considered his case chiefly one of deranged nerve centres.

There is pallor or lividity, drenching perspiration, weakness of both voluntary and involuntary muscles, the circulatory and respiratory functions being profoundly embarrassed. Sensory motor phenomena are those of exhaustion rather than of the irritable, responsive to the least stimulation, type—there is the tendency to sleep and stupor rather than to convulsions. Now, although parodoxical, it is no inconsistency that the other notable symptoms may become prominent such as fibrillary twitchings and violent painful cramps of muscles of the abdomen, arms, and legs; these can hardly be due to any systemic nerve poison, but must be consequent upon a local dehydration of muscle tissue, with a diminished alkalinity of plasma from excessive production and retention of katabolic acids (sarcolactic, carbonic, and lactic), which have been shown by McDougall and E. B. Meigs to attend muscle rigor; the accumulation of products of tissue metabolism generally may account for vasomotor paresis and shock. It is, of course, important to distinguish cases of intestinal cramps due to dietetic error or ice water ingestion from the heat cramps of abdominal wall muscles.

The etiology and incipiency of heat exhaustion need not be at variance with those of sun stroke except in intensity; the assumption is tenable that in sun stroke the factors are so fulminating and of such an overwhelming character that heat production and loss are promptly deranged, whereas the symptoms of heat exhaustion represent the sustaining and finally, failing efforts upon the part of the human body to overcome its adverse environment. I shall be content to enumerate these factors in causation of heat exhaustion, no one of which has been certainly eliminated as either contributory or immediate; no special combination seems to be essentially determining: Chronic alcoholism with fatty infiltration of the heart—dilatation when called upon to pump more blood through lungs and skin under stimulation of excessive heat; dissipation or debility from disease or unsuitable hygiene, such as overcrowding; hard muscular work (Edsall) and unrelieved fatigue; insufficient circulation of air and wet-bulb temperature from 85° to 95° (J. S. Haldane's critical point and Harvey Sutton's vicious circle); lack of habituation; constricting or heavy clothing; fright or panic induced by occurrence of other cases, as shown by Oswald Rees, R. N.; loss of sleep (H. M. Welch); improper nutritive ratio—excess of protein and deficiency of carbohydrates; insufficient assimilation of water; to these may be added Senftlenben's observation of blood concentration, red-corpuscle destruction and hemoglobinemia more commonly expected in sun-stroke; arterial anemia, toxin and fibrin ferment accumulation from preponderance of skin over kidney excretion and leukocyte destruction (Maurice de Fleury); predisposition by former attacks (W. H. Cameron and Logan Clendening); the actinic theory of Lieut. Col. R. J. S. Simpson is merely mentioned to be excluded in our cases among the fire-room force.

For the physiologist no doubt the inclusion of so many causative factors, direct or remote, is unsatisfactory, confusing, and a confession of ignorance; for the hygienist their probable relation has given such hints that the removal of few or many has contributed to the great decline in heat exhaustion and cramps in the navy. If I were called upon to single out any one remedy to bring about this result more than another it would be the increased circulation of air where the men work rather than any mere lowering of temperature or humidity.

STATISTICAL TABLE OF HEAT AFFECTIONS IN THE UNITED STATES NAVY AND MARINE CORPS, 1861–1911.

Year.	Mean strength (medical returns).	Cases.	To hospital.	Invalided from service.	Deaths.	Number of sick days.	Total damage in percentage of sick.
1861	20,000	5				Apparently all insolation.	
1862	25,905	34					
1863	40,000	16					
1864	43,787	27					
1865	32,641	3			1		
1866	17,193						
to	No data available in published reports						
1872	11,570						
1873	12,723	14					
1874	13,870	19					
1875	10,141	5			1		
1876	11,138	8					
1877	7,461	17	"Heat exhaustion" (2 cases); first mentioned on Asiatic station.				
1878	7,806	10	..	..	..	26	.000791
1879	8,869	Not mentioned in reports.				..	.000000
1880	9,003	23	..	5	..	89	.026668
1881	9,546	18	3	1	..	50	.005729
1882	9,371	12	1	..	..	61	.001576
1883	9,197	10	1	1	..	166	.009670
1884	9,959	18	..	..	..	72	.001797
		"Heat exhaustion" really begins.					
1885	9,191	20	1	..	..	103	.003070
1886	9,188	5	..	..	1	20	.005442
1887	9,618	41	1	..	..	226	.006438
1888	9,955	25	..	..	1	96	.007857
1889	11,219	33	3	..	..	216	.005275
1890	11,768	37	..	..	..	257	.005983
1891	11,501	41	3	..	..	195	.004645
1892	11,775	29	2	..	1	135	.007760
1893	12,109	51	1	1	..	293	.010758
1894	12,520	44	..	..	2	190	.012145
1895	12,671	92	..	..	1	359	.011562
1896	13,768	59	3	..	1	257	.008622
1897	15,229	81	4	..	1	339	.010356
1898	23,038	512	19	7	..	2054	.039019
1899	20,113	154	10	1	1	939	.017594
1900	22,977	128	13	..	5	442	.015798
1901	26,101	95	4	2	1	643	.012352
1902	30,249	95	5	1	1	503	.007757
1903	36,534	94	2	1	2	333	.006543
1904	39,450	92	13	..	..	569	.003941
1905	39,620	160	3	..	..	655	.004529
1906	41,690	168	15	3	1	739	.009559
1907	44,083	86	4	4	..	504	.007448
1908	50,984	106	17	1	..	801	.005220
1909	55,550	155	6	3	..	703	.006090
1910	56,721	125	..	1	..	391	.002755
1911	61,399	88	..	1	1	423	.003516